Aalto University
School of Business

THE ROLE OF EXCESS RESERVES IN MODERN MONETARY POLICY AND BANKING

Master's Thesis
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Abstract of master's thesis

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Abstract

Regulatory changes after the great financial crisis allowed the Federal Reserve to pay positive interest on excess reserves (IOER) held by depository institutions. The increase of excess reserves in Federal Reserve System was a direct consequence of Quantitative Easing, that effectively made the market for reserves saturated meaning, that the Fed can change its interest rate target and its reserve supply independently. IOER has since then became the single most important policy tool for Fed to target its interest rates and has made the monetary policy more effective. In this thesis, I will provide an overview on IOER as a monetary policy tool and its implications for the banking sector. In empirical part I show evidence, that the demand for reserves is no longer fully saturated as the interest rate target has been raised and the balance sheet unwinding (Quantitative Tightening) has started during the year 2018. Excess reserve scarcity could pose serious systemic risks in the banking sector and could cause difficulties for Federal Reserve in its Quantitative Tightening.

Keywords Excess Reserves, Interest on Excess Reserves, IOER, Monetary Policy, Floor System, Quantitative Tightening, Federal Reserve balance sheet, Demand for Reserves, Interest Rate, Overnight Reverse Repurchase Agreements

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The Role of Excess Reserves in Modern Monetary Policy and Banking

Executive Summary

This paper provides a summary of what role excess reserves and interest paid on excess reserves play in Federal Reserves' monetary policy. Fed has had the legal authority to pay interest on excess reserves (IOER) held by depository institutions after the financial crisis and IOER has since then become one of the most important policy tools in central banks' disposal.

I will first lay down the basic institutional background behind the rise of held excess reserves in the Federal Reserve system and go through the basics behind the current monetary policy regime, when markets for reserves are saturated and IOER is positive. We will find out that under current monetary policy regime, Fed can steer its interest rate target with IOER more effectively than before, when the main instruments for interest rate targeting were Overnight Reverse Repurchase Agreements (ON RRP, rate at which banks can lend reserves overnight) and Open Market Operations (selling and buying reserves constantly in the market to keep interest rate in its target zone).

After institutional background, I will discuss, what the primary factors behind demand for reserves in financial markets are. Excess reserves can act as highly liquid safe asset in a market where central banks have sucked most of the AAA-graded government bonds out of the market via their QE-programmes. Simultaneously, central banks have effectively manipulated the short-term interest rates and changed the behaviour of banks in their short-term funding needs.

In empirical part, I will study the demand curve for reserves using two distinct price measures for reserves. I find implications that markets might no longer be fully saturated with excess reserves, but it will demand more time and deeper research to make any far-fetching conclusions yet.

Introduction

After nearly a decade of Quantitative Easing in the aftermath of the great financial crisis, the banking system in the United States has been saturated with excess reserves. Excess Reserves are reserves held by the depository institutions in the balance sheet of Federal Reserve System that exceed the minimum reserve requirements. Markets for reserves is said to be saturated when the demand curve for reserves becomes horizontal. The supply of excess reserves got saturated after Federal Reserve bought assets in its Quantitative Easing programmes: as the amount of excess reserves grew substantially to trillions of dollars, banks eventually became indifferent to holding more reserves as their opportunity cost regarding other short-term investments fell in unusually low interest rate environment. Usually increase in voluntary excess reserves has been a sign of risk minimization of commercial banks during especially harsh economic downturns. Aside from the current situation, only twice in the Federal Reserve history, have the excess reserves increased significantly: after the market crash of 1929 and after the 9/11.

Amount of excess reserves in the Federal Reserve System hit all time high of 2.6 trillion US dollars in 2016 as a direct consequence of Quantitative Easing Programs (three large asset purchase programs conducted by the Fed after the financial crisis) meaning that they effectively formed over half of the entire Federal Reserve balance sheet liabilities. After increasing interest rates and a gradual shrinking of the central banks' balance sheet, reserves have decreased since then, but still amount over 1.7 trillion dollars and could still pose a massive money supply risk in a case of a central bank run of all commercial banks simultaneously. Since the excess reserves are essential in understanding how Quantitative Easing works, it is also a pivotal research subject now, as Federal Reserve has entered the tightening phase of its monetary policy: Quantitative Tightening.

Interest on the excess reserves (IOER) has become also more important monetary policy tool for Federal Reserve than in the past. It is argued, that setting IOER at the top level of its interest rate target, Fed essentially creates an artificial floor for short-term market rates and therefore makes monetary policy targeting more effective. Usually Fed has conducted Open market operations to keep interest rates in their target in the so-called Corridor system of monetary policy. Now, thanks to saturated markets of excess reserves, we have entered a new monetary policy regime: Floor system interest rate targeting.

As the Fed normalizes its balance sheet by shrinking its exposure to bought government bonds and simultaneously shrinks the supply of available excess reserves in the markets, banks are forced to substitute their reserve holdings for cash or bonds. This together with rising interest rates is essentially what Fed will be doing during the Quantitative Tightening of its monetary policy. Federal Reserve will reduce its assets by letting purchased bonds run into their maturity. As the asset side of Federal Reserve balance sheet shrinks, also the liabilities side (mainly excess reserves) will also decrease by same amount. The maximum monthly amount of balance sheet reduction will be $50 billion (Chris Waller, 2018).

This again increases the risk exposure of banks from the current situation and could lead to a strong market correction in the next months as at the time also interest rates are going up rapidly. As well as being important tool for monetary policy, excess reserves are also an important buffer against systemic risks in the banking system, since they have effectively decreased banks risk exposure in interbank markets. Reducing excess reserves could then expose these systemic risks again in the financial sector. Even though Federal Reserve is inclined to decrease its reserve holdings in cautious and gradual manner, it is possible that some emerging systemic risks might be left unnoticed: shrinking of reserves might affect different depository institutions asymmetrically depending on their ability to cope to changes in the lending market. Therefore, to understand the risks of increasing systemic risk,

it is important to discuss how reserves have affected banks decision making and current credit supply in the banking system.

The purpose of this thesis is to provide an overview on how excess reserves in Federal Reserve balance sheet have changed the nature of modern monetary policy. In the early years of post-financial crisis, excess reserves were not especially studied subject, but now, as the central bank balance sheet shrinking becomes more relevant, more and more research has been made on the effects of reserves in interest rate targeting and in banks perceived risks and credit supply. I will assess the nature of current monetary policy with IOER as one of Federal Reserves' main policy tool and discuss the profound effects of QE in demand for excess reserves in the banking sector. Institutional and historical background will cover the important changes in US monetary policy after 2008 and walk through the difference between the previous Corridor system monetary policy and the current Floor system. The effectiveness of the Floor system depends heavily on saturated markets for reserves, since it allows the Fed to choose its interest rate target and the amount of reserves independently (Reis, 2016). When markets are saturated with reserves, the demand curve for reserves is horizontal and we could expect the current monetary policy to be effective until the supply of reserves fall substantially and move to the elastic part of the curve. It can be argued, that because the Floor system requires less Open Market Operations by the Federal Reserve, the current monetary policy has become more effective after the increase in excess reserves.

Efficiency of reserves and different regulations in banking sector after the financial crisis can though be criticized. I will review different views on reserves and interest on excess reserves. The debate of monetary policy efficiency and banking regulation against profitability of banking sector goes way back to Friedman and has since been reasoned for and against among economists. So far, the Fed and the US government has opted for more efficient monetary policy and more prudent regulations

despite possible welfare effects of positive IOER. I will finish the institutional review on different exit strategies Fed could be using in its Quantitative Tightening. Federal Reserve has long communicated to the markets about its intensions of decreasing its current balance sheet closer to pre-crisis levels which would mean decreasing current level of excess reserves substantially lower. This could imply problems to current interest rate policies, since the amount of reserves could fall beyond the point of saturation making the Floor system inefficient. I will discuss this issue in greater detail later.

After the discussion on efficiency of IOER and exit strategies, I will review the demand for reserves, since the demand curve for reserves will also be my research subject in later empirical part of this thesis. The demand for reserves has been an important research topic long before the unconventional policies of the past years. Especially the relationship between interest rates and reserves has been somewhat popular research topic in monetary economics (i.e. Dow, 2001). To put shortly, before QE the increase in reserves was deemed merely as a hedge for uncertainty in the banking sector. In more detail, reserves were a hedge against uncertainty about the counterparty's true balance sheet and solvency. In the current situation with voluntary excess reserves though, the situation becomes more interesting: Federal Reserve has effectively manipulated the short-term interest rates lower and changed the behavior of banks in their short-term funding needs. Chapter 2 will review how the Federal Reserve has succeeded in manipulating the banks' demand curve for reserves by creating safe asset scarcity with its Quantitative Easing programs.

In empirical part, I will replicate the regression analysis of demand for reserves made originally by Ricardo Reis in his paper "Funding Quantitative Easing to Target Inflation". He found that the markets became effectively saturated with excess reserves after the end of 2011. My contribution would then be to extend his analysis with data from the last quarter of 2016 to the end of 2018. A lot has happened in the

matter of excess reserves in this time frame: Reserves have shrunk hundreds of billions of dollars and interest rates have been hiked five times. My hypothesis in this study is that markets are no longer fully saturated with excess reserves which effectively means, that Federal Reserve can shrink its reserves by adjusting the spread between IOER and its interest rate target. The approach is far from perfect due to its simplicity but is still a useful tool among many others to find real answers to monetary policy problems we are facing today. I indeed find some evidence that the demand for reserves might already be approaching the elastic part of the demand curve meaning that the markets are not fully saturated with reserves anymore. Alternatively, banks could already be preparing in advance for the situation, where reserves become scarce again. Anyhow, my results indicate a difficult upcoming year regarding monetary policy and liquidity in the banking sector. This implies difficulties to the Federal Reserve balance sheet unwinding and could reveal some serious systemic risks in the near future, that I will discuss at the end of this thesis.

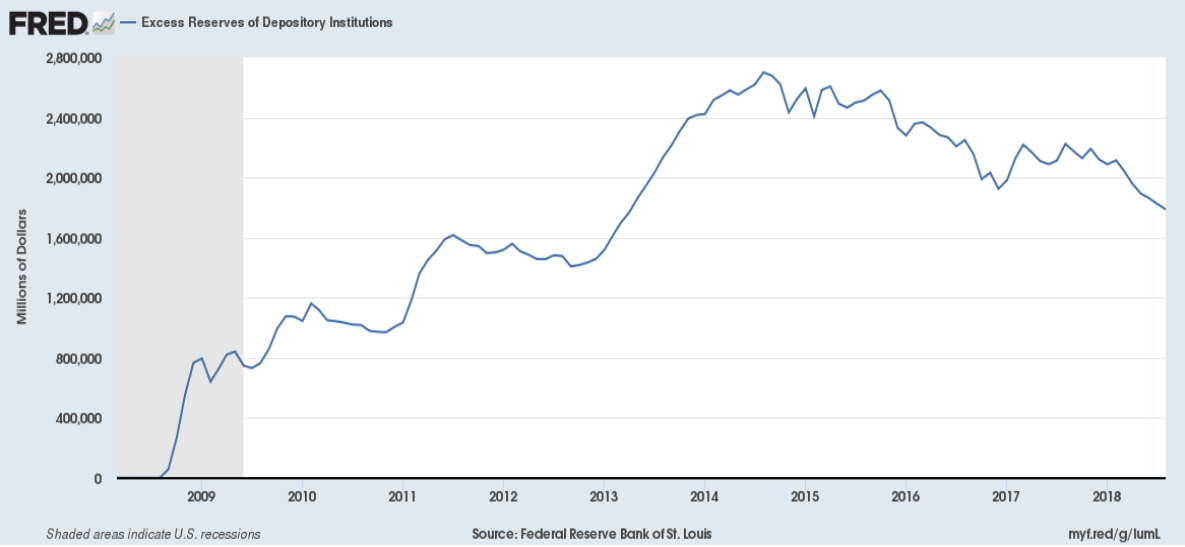
This paper is constructed as follows: first I will lay down the historical and institutional background in chapter 1. This provides the insights on the use of IOER and the reasoning behind increasing excess reserves in the market. I will also present the theoretical background of IOER and explain the main differences in the modern interest rate targeting compared to previous monetary policy regime. Then, I will discuss the efficiency implications of interest on reserves and introduce different exit strategies for Quantitative Tightening. In chapter 2, I will concentrate mainly on the demand of reserves. Where does the demand for reserves come from? How has the Fed manipulated the short-term interest markets with its monetary policy? In this chapter, I will also present excess reserves as new safe assets in the market with scarce supply of investment-grade assets. In chapter 3, I will present my empirical work and replicate the study of Reis of the demand for excess reserves. Finally, I will discuss my findings and conclude this paper.

1. Institutional and historical background

In this first chapter, I will discuss the history and institutions behind current monetary policy. I will start by going through the main effects of Quantitative Easing and reasons behind the increase in excess reserve holdings. The main takeaway from this chapter is to describe the shift to the use of interest on excess reserves (IOER) as Fed's new main policy tool of interest rate targeting. After explaining the change in monetary policy regime, I will discuss different efficiency implications of this monetary policy. Finally, I present different exit strategies Fed could be using during the Quantitative Tightening process.

1.1 Quantitative Easing and the Rise of Excess Reserves

Figure 1: Excess Reserves of Depository Institutions 2008-2018 (Federal Reserve Bank of St. Louis)



Excess Reserves of Depository Institutions grew from practically zero to nearly 2.7 trillion US dollars in less than 8 years. From the figure above, we can also see when these reserves have been accumulated: during three different QE rounds from 2009 to 2015. After Large Scale Asset Purchases (LSAP) excess reserves became the single

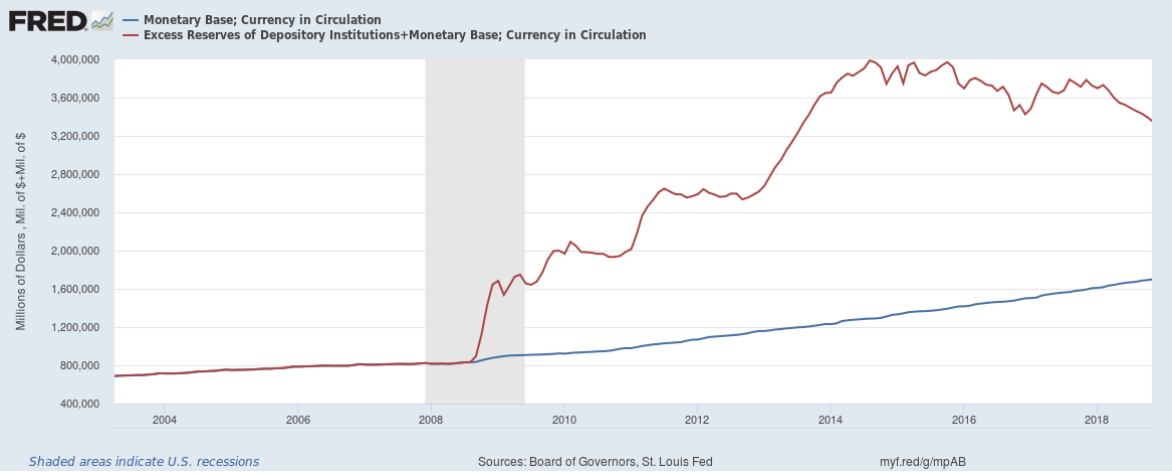
most important item of the Federal Reserve Balance sheet. What makes this fact especially interesting, is that reserves are in nature, straight substitute for cash. Therefore, they can pose an inflationary pressure if large amount of depository institutions decides to bail in their reserves for cash.

To clarify, Quantitative easing was never about "money printing" like many of its critics have pointed out. By purchasing sovereign bonds from the market, Fed substituted them for reserves in its own balance sheets liabilities. Therefore, money supply in practice, remain untouched. The interesting question here is why banks were seemingly satisfied in holding such large amount of reserves in their assets when they could have easily swapped these holdings to cash and use it for supplying credit in markets. To tackle this issue, let's first examine the market situation of the last ten years to understand why it has been so lucrative for banks to hold excess reserves.

Firstly, Federal Reserve began paying interest on excess reserves (IOER) to depository institutions to hold up inflationary pressures in the money supply. When central bank pays positive interest on reserves at market rates, price level in the economy can be decoupled from total monetary assets: inflated monetary base does not necessarily imply higher price level, if the reserves are controlled and constrained (Ennis, 2018). This means, that Fed has the composition of its liabilities under control, either by being able to force banks to keep their acquired excess reserves with regulation or by incentivizing banks to hold reserves by paying higher IOER. The third option would be to substitute reserves to other than currency (which would increase inflationary pressures). Currency in circulation is usually referred to as working monetary base (excludes reserves from monetary base). Figure 2 below show cases the great divergence between actual monetary base and working monetary base as a result of QE. If Fed would lose its control over reserves, it would also essentially lose control over its working monetary base growth.

IOER is then an important tool for Fed to control the price level in the economy stable even as the actual monetary base has been inflated. However, there could still be a limit on the supply of reserves where the actual monetary base becomes incompatible with stable prices even with positive interest on excess reserves. The amount of excess reserves banks can hold is tied to the size of their respective balance sheets and since banks face capital requirements together with shrinking liquidity in the short-term money market, the demand for reserves is linked to the total amount of bank capital available in the economy. If bank capital becomes scarce again, the cost of holding more reserves increases and their demand decreases. As more reserves would be substituted to currency, working monetary base starts to grow and the price level would again move together with the actual monetary base growth (Ennis, 2018). This implies, that Federal Reserve cannot increase its balance sheet size indefinitely without causing possible inflationary pressures in the price level. Inflation risk linked to the QE is then not completely ruled out and sets restrictions to the current and future easing policies.

Figure 2: Excess Reserves and Currency in circulation (St. Louis Fed)



I will treat excess reserves as a safe asset for the banking system. Because of this, banks were inclined to swap their sovereign bond holdings for another safe substitute in a form of excess reserves, since they provide a better liquidity and contain

no sovereign risk. The only risk in excess reserves in theory is monetary policy risk, that is, a case when markets lose their trust in Federal Reserve as a lender of last resort and its capability of keeping monetary policy stable. This kind of Ponzi-like risk in central banking has always been a possibility, but of course, the real chance of that happening is considered very low (since it would essentially blow up the whole monetary system as it exists now). Aside from lowering risks in the market, IOER provides banks an important incentive for not to reallocate their assets to cash.

Secondly, despite large increase in excess reserves, credit supply has not been necessarily negatively affected. Record amount of credit has been given to corporations and households altogether. Total US household debt has grown to over $13.5 trillion (New York Fed) while US corporate debt has climbed to over $6.2 trillion (St. Louis Fed). Excess reserves created in the QE programs indeed led to higher loan growth and riskier lending activity. Reserve creation can then be seen as one of the important transmission channels of QE to economic activity (Kandrac & Schlusche, 2018).

Figure 3: US Corporate debt 2003-2018 (St. Louis Fed)

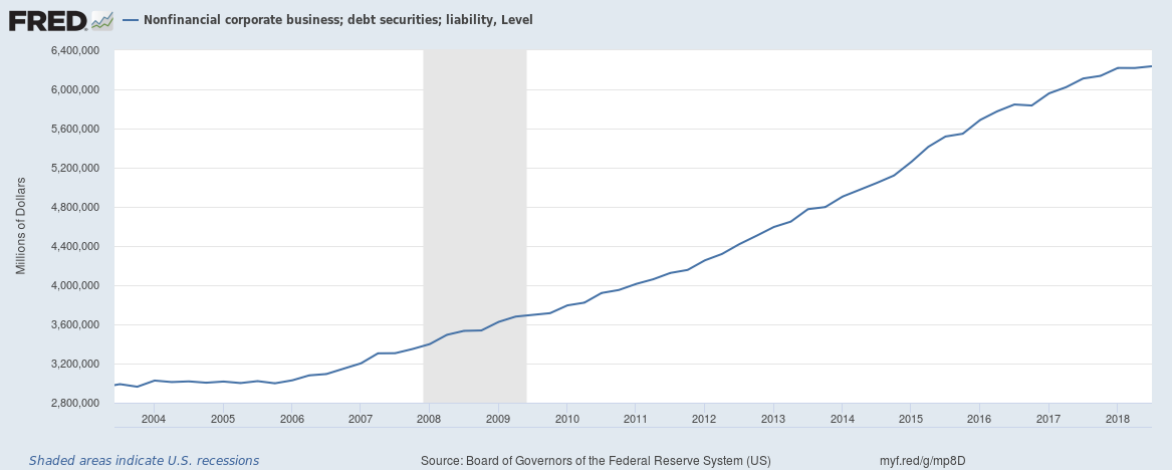
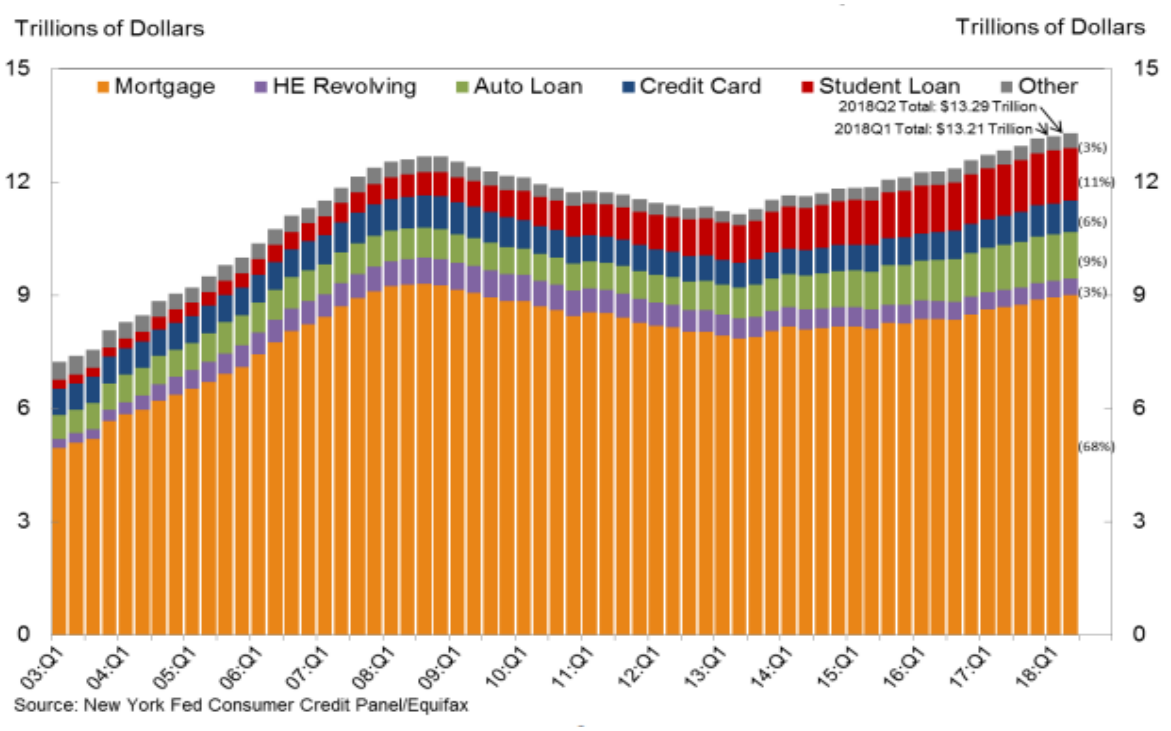


Figure 4: Composition of US household debt 2003-2018 (New York Fed Consumer Credit Panel/Equifax)



Thirdly, risk exposure of depository institution in interbank markets should have, in theory, decreased, since the need for interbank lending in short-term money markets have shrunk to minimum because of abundant excess reserves. Reducing these risks was initially one of Fed's main goals in its monetary policy after Lehman collapse when the trust between financial institutions bottomed. Higher interbank borrowing costs after the initial Lehman crisis was caused by banks' fears over their counterparties solvency and ability to pay any unsecured debt back (Taylor & Williams, 2008).

The role of excess reserves and Federal Reserve as a lender of last resort to provide short-term financing in banking sector have then become even more relevant (Money and Banking, 2018). The increased stress in the financial system and in interbank-market has also become more visible as the volatility in Libor-OIS spread has sharply increased during 2018. Libor-OIS spread is usually seen as one of key measures for credit risk and illiquidity concerns in the banking sector. The OIS

(Overnight Indexed Swap) rate is the most relevant measure for market expectations of future federal funds rate and LIBOR (London Interbank Offered Rate) reflects the expectations for future overnight rates and credit risk (Sengupta & Man Tam, 2008). Increase in the spread then could be associated with liquidity problems in the market.

Finally, reserves have a unique role in federal funds market: reserves are used in handling daily activities of depository institutions in interbank-markets. As an alternative to using reserves to meet their daily transactions with other depository institutions, banks can also borrow from overnight repurchase facility, which acts as the other important policy tool for Federal Reserve in interest rate targeting. I will cover both tools in greater detail in later chapters.

1.2 New Monetary Policy Regime and interest rate formation: from corridor to floor system

Before 2008, Federal Reserve did not have legal authority to pay interest on excess reserves held in its system and therefore IOER was not seen as a viable policy alternative for reigning monetary policy system. Only after the emergency laws implemented by the US senate after the Lehman Brothers bankruptcy in October 2008 became IOER one of the main instruments of Federal Reserve monetary policy toolkit. To examine the importance of this change in monetary policy regime, let's review the main aspects of the previous regime without interest on reserves compared to the current regime with saturated excess reserves in the Federal Reserve System.

Figure 5 (Ireland, 2012)

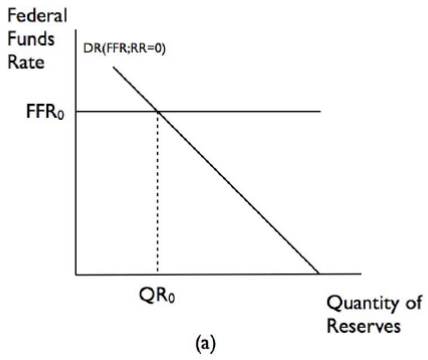
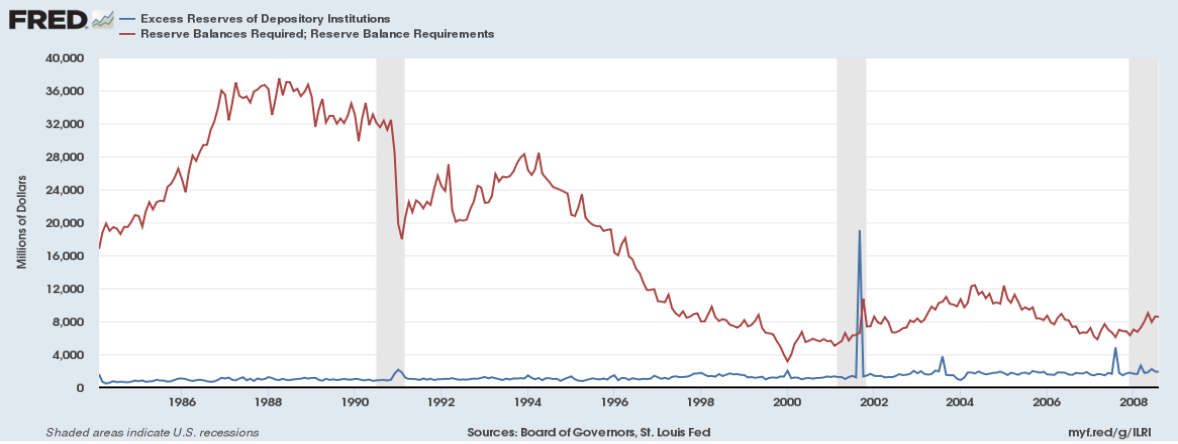


Figure 5 presents the simple downward sloping demand curve for reserves when central bank does not pay interest on its reserves. When federal funds rate falls, banks are more inclined to hold reserves, since the cost of holding them is lower. The lower the interest rate, the higher are the reserves held by depository institutions. Simply put, Federal Reserve needs to issue quantity of QR_0 reserves through Open Market Operations (OMO) to hit its interest target FFR_0 in the market. Fed as all major central banks then created an environment, structural liquidity deficit, where reserves became scarce safe asset in the markets: central bank only issued just enough reserves for banking system to keep its interest rates on target and to ensure that banks were able to meet their minimum reserve requirements (Berentsen et. al, 2015).

In this way, hitting the federal funds rate target is much more difficult task than many could expect. Keeping rates in central bank's target required constant operations in the markets to keep upward and downward pressures from interest rate speculation at minimum. Federal Reserve like many other central banks, requires banks to hold certain percentage of their liabilities as reserves in central banks' balance sheet. Big institutions (with net transactions over $124.2 million) are required to hold 10 % of their liabilities as reserves in Federal Reserve System (Federal Reserve). Before Fed began paying interest on excess reserves, reserves held by depository institutions consisted mainly of required holdings and the amount of excess

reserves was kept at minimum. Only during big political shocks like after 9/11, the amount of excess reserves has spiked significantly due to uncertainty in banking sector (Figure 6). Since banks cannot lower their reserve holdings below the minimum reserve requirements, demand curve becomes effectively vertical on point of regulated required reserves. Hence, reserves cannot fall completely to zero even if the federal funds target increases indefinitely. I will discuss the effect of minimum reserve requirements in greater detail later in next chapter.

Figure 6: Amount of excess reserves relative to required reserves was not significant before the financial crisis. (Board of Governors, St. Louis Federal Reserve)



The system where Federal Reserve targets federal funds rate by issuing reserves via open market operations by the trading desk of the Federal Reserve Bank of New York is referred as Corridor system of monetary policy and was on effect for many decades until the financial crisis. After the financial crisis and after trillions worth of Quantative Easing (QE), the amount of excess reserves in Federal Reserve System however, ballooned manifold compared to required reserves.

Figure 7: Excess reserves of depository institutions after 2008 (Board of Governors, St. Louis Federal Reserve)

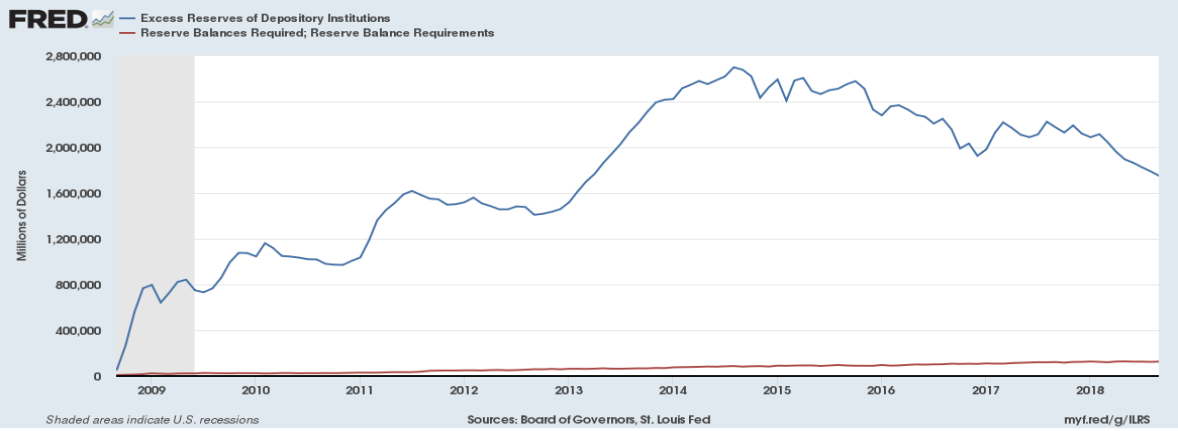
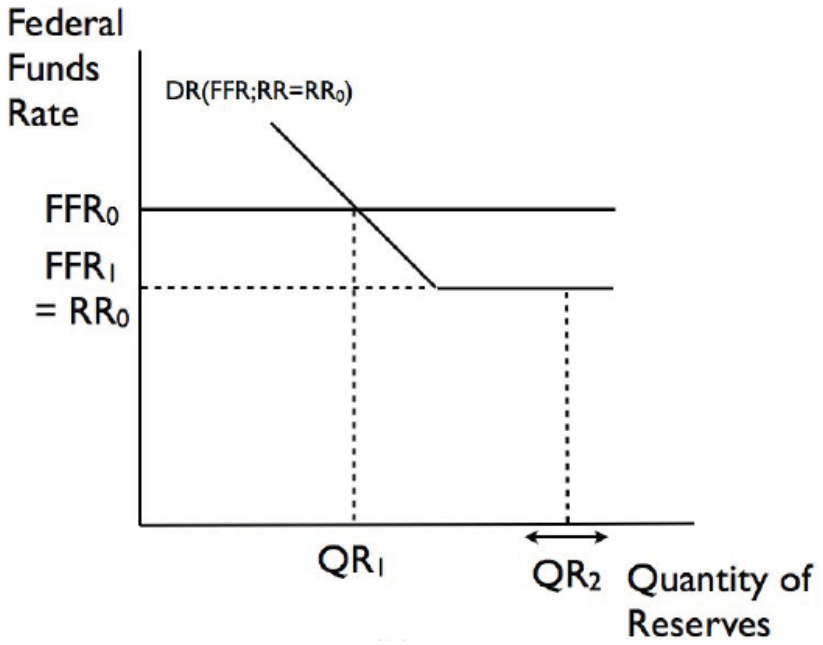


Figure 7 shows the dramatic increase in excess reserve holdings beginning from September 2008. The growth rate of US monetary base during last 10 years has been on average 16 %, most of which has been an increase in the excess reserves. Simultaneously every attempt of increasing inflation has been lacklustre and general price level has grown under 2 % on annual average. Excess reserves have been increased during the three QE-rounds conducted by the Federal Reserve after 2008.

Quantative Easing has been an area of intense research in macroeconomics during this decade. Most of the research have tried to understand the effects of large asset purchases by the Fed to the real economy and banking sector (for example: Gertler and Karadi, 2011) or transmission channels of QE (i.e. Krishnamurthy & Vissing-Jorgensen, 2011), but until 2016 the effects on balance sheet interdependence of depository institutions and central bank has been less studied. Since excess reserves and the interest paid on excess reserves have become the most important policy tool for Federal Reserve and the key for ending the decade of easy money (interest rates near zero, abundant reserves for depository institutions), I will now present the simple rationale behind the current monetary policy regime: the Floor system.

Figure 8: Floor system of monetary policy (Ireland,2012)



Unlike in the previous system, Federal Reserve can now set a floor to which the federal funds market rate can fall by paying interest on excess reserves (IOER). It sets the IOER at the upper boundary of its rate target (RR_0). This effectively decreases the demand for open market operations, since rates cannot fall under the floor set by the IOER for longer period. For any profit-seeking depository institution, it would not make any economic sense to lend at interbank markets with rates under IOER, when they could make more money by just parking their money in Federal Reserve balance sheet and earn interest on their reserves. This means the Fed doesn't need to conduct open market operations in its targets lower bound since IOER provides the economic incentives for banks to push interbank market rates above that floor. Federal Reserve has indeed invented a new approach into the floor system: in a way it is a floor with a subfloor, since overnight repurchase agreement rate is set at the lower end of the interest rate target. Federal Funds rate has usually lied between these two rates. It was not until Fall 2018, when Federal Funds rate and IOER reached parity. Thus, to put shortly, the IOER sets the floor, and the ON-

RRP rate sets the subfloor. I will explain these policy tools in chapter 2.3 in greater detail.

In the figure 8 then, Federal Reserve can set IOER at RR_0 and reach its target level (federal funds rate between FFR_0 and FFR_1). It can still conduct open market operations in the upper bound of its target level and keep rates near FFR_1 by issuing QR_1 reserves in the market. However, it can also decide to let interest fall on the floor created by the IOER by saturating the markets with excess reserves (Reis,2016). Then the Quantity of reserves could be anywhere on the horizontal line of demand curve: for example, on QR_2. Note, that unlike in previous system where we had the downward sloping demand for reserves, now IOER makes the demand curve horizontal in RR_0. In general, IOER has shifted the demand curve for reserves horizontal in FFR_1) but has not changed the slope above the RR_0.

Figure 9: Interest Paid on Excess Reserves (Board of Governors of the Federal Reserve System)

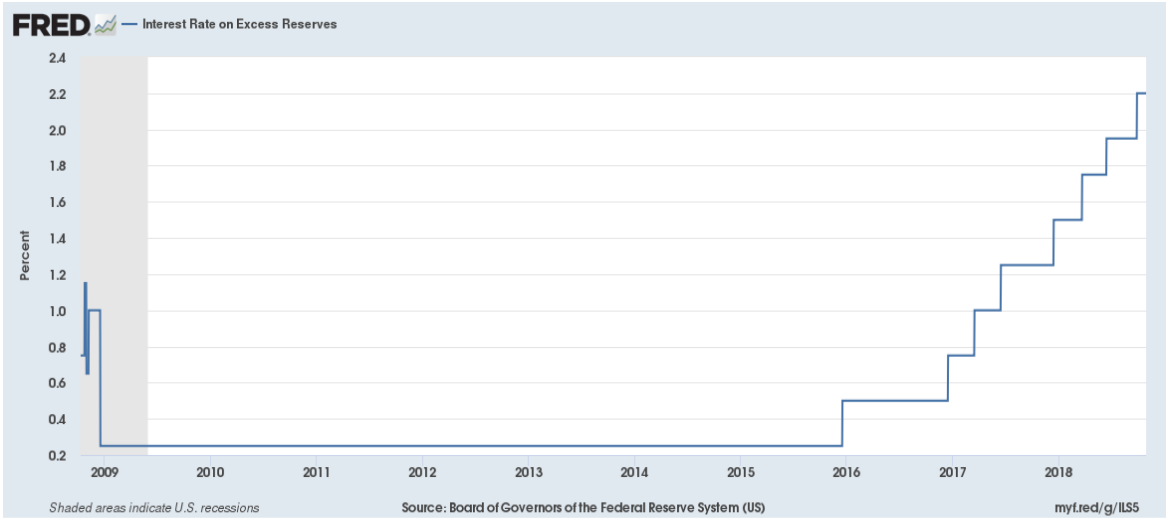


Figure 9 shows the interest paid on Excess Reserves after it was legalised in late 2008. It was initially set at 0.75 % and was increased as high as 1.15 % in October 2008. However, it was quickly decreased to 0.25 % as the Fed begun lowering its interest rates to near zero territory. During the Quantative easing –phase of mone-

tary policy, Fed did not actively use its new mandate of IOER. Only after 2016, under chair Janet Yellen, the Fed begun using it as its main instrument for raising interest rates in US in the manner described as floor-system above. IOER could then be mainly seen as a tool for Quantative Tightening rather than Quantative Easing. The goal of QE was primarily to increase the amount of reserves in the Federal Reserve balance sheet. Ricardo Reis (2016) pointed out, that the first two rounds of Large-scale Asset Purchases (LSAP) were intended to lower federal funds rate near zero while simultaneously pushing the amount of excess reserves to horizontal line of demand curve. The third and final round of LSAP only increased the excess reserves and left rates untouched, since the rates were already near zero (Reis, 2016).

This explains an important aspect in the current monetary policy regime: to find its target near the floor set by the IOER, Fed needs to issue abundant amount of reserves to markets to keep them saturated with reserves. This in essence means that any bank in Federal Reserve System is indifferent to holding reserves and lending them at current interest rate levels in interbank markets. According to Reis, US markets have been effectively saturated since October 2011 and the demand curve for reserves has been horizontal at least until the beginning of tightening process of monetary policy in 2016. US markets have then moved from structural liquidity deficit to structural liquidity surplus environment.

Figure 10 Demand for reserves (Ricarco Reis, 2016)

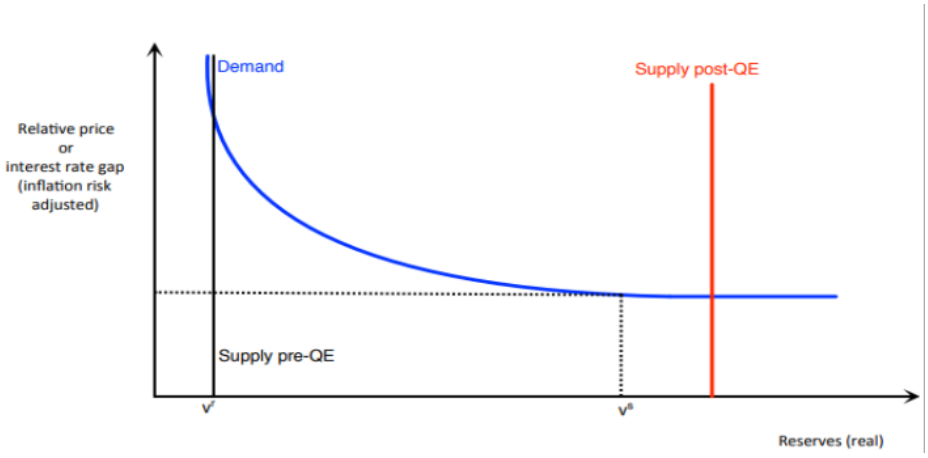


Figure 10 (from Reis, 2016) is a modification to the previous figures portraying the demand for reserves. Now we have a vertical line at v^r that was the required reserve balances before QE. In addition, demand for reserves is vertical near this level, since banks cannot freely choose the amount of reserves they wish to hold at current interest rate levels. The rationale behind QE was then to push down the relative price between IOER and federal funds rate and effectively reach the horizontal part of the demand curve beyond v^s. When markets became wholly saturated with excess reserves, Fed was able to issue any amount of excess reserves with its asset purchases independently of current interest rate level. Regression analysis made by Reis in 2016, which I will replicate with new data later in this thesis, proves that the markets in US were in fact saturated with reserves and the last QE-round did not have any significant effect on interest rates, which gives proof for this important hypothesis.

1.3 Efficiency implications of reserves and IOER

Next, I will discuss further the efficiency implications of paying positive interest rate for reserves. Discussion is tightly related to other banking regulations such as minimum reserve requirements. In this section I will review different advantages and disadvantages of minimum reserve requirements and positive IOER and then compare US rate policies to Europe and Japan, where both European Central Bank (ECB) and Bank of Japan (BoJ) have opted using negative interest rates for reserves.

The advantages of required reserve holdings come from prudential implications, impacts on monetary control and on management of aggregate liquidity. Reserve requirements ensure that depository institutions hold at least some high-quality and liquid assets. The main objective is to be able to meet even the unexpected short-run demand in the interbank markets: liquidity problems could come from domes-

tic or international sources, so reserve requirements offset the systemic risks between banks during shocks in the banking sector. Also, this would directly ensure trust between banks, since they know that their counterparties in interbank market are regulated to hold at least some liquid assets to meet their obligations. Aside from liquidity and prudential considerations, reserve requirements act as important policy tool for central bank to control the credit growth and liquidity in the banking system (Gray [IMF], 2011)

Advocation for paying positive interest on reserves has been around for many decades. Perhaps most famously, Milton Friedman suggested interest on reserves at market rates to offset distortions associated with regulatory required reserve holdings. He argued that requiring banks to hold non-interest-bearing reserves related to their assets, essentially meant taxing depository institutions for their deposit volume (Friedman, 1960). As a consequence, minimum reserve requirements then cause deadweight-losses to society: banks have incentive to discourage its customers from keeping as much money as they would otherwise want at their bank accounts. Banks can alter the behaviour of its customers for example by paying lower interest on certain accounts. This social cost of forcing minimum reserves could then be offset by paying interest for reserves at similar rate to what banks would reasonably expect otherwise by being able to use their regulated funds (Woodford, 2002).

Reserve requirements however are an important tool for Federal Reserve to control the credit flow in the economy by capping the maximum amount banks can credit with their monetary assets. Moreover, as we have earlier discussed, minimum reserve requirements offer Fed a tool to manipulate the demand for reserves to become vertical at given regulated level. Without the vertical part of the demand for reserves, banks could choose to liquidate all their reserve holdings, leaving Fed without a policy tool to adjust their interest rate targets. So, in this sense, while reserve requirements might cause inefficiencies in the economy, they also make monetary policy effective as it is.

However, minimum reserve requirements might cause other frictions in the financial markets as well: banks were inclined to hold excess reserves (even before the markets became saturated) if the penalty from not being able to meet required levels of reserves was costly (i.e. liquidation of high-yield assets). Keeping more reserves than was regulatory necessary then increased the welfare loss of required reserves further (Tobin, 1982).

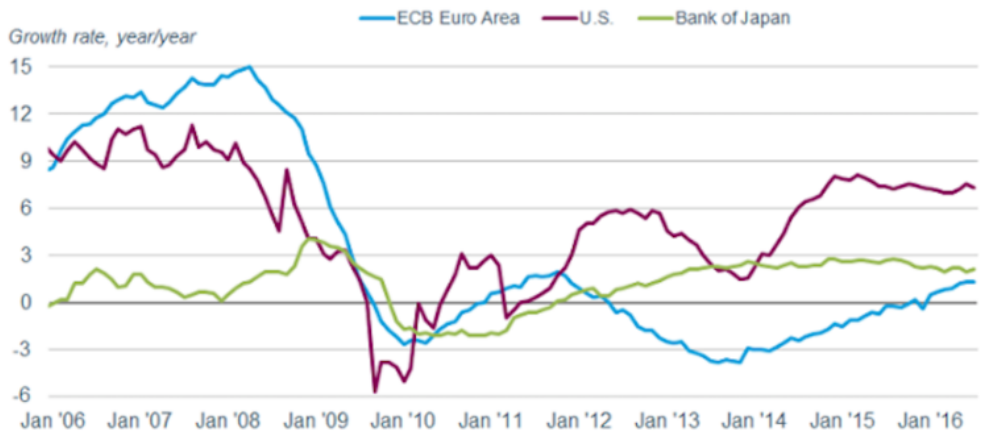
Aside from social costs stemming from decreasing supply of deposits available, reserve requirements can cause unnecessary volatility in federal funds rate, thus causing monetary policy inefficiencies. Fed for instance, calculates the required reserves as average reserves over two-week period, which before adoption of the modern monetary policy, made volatility in federal funds market higher usually during the last day of the observation period (Furfine, 2000). These monetary policy problems are of course solved in the floor system interest rate setting when demand for reserves is saturated and reserves are paid interest. This system also means less daily volatility in federal funds rate, as banks don't need to tweak their reserve holdings so actively. Floor system again, is then more effective system to target federal funds rate and reduces the need for mandated reserve requirements.

So, Federal Reserve opted for more effective monetary policy when it steered the market to reserve-surplus environment and begun paying interest on reserves. In addition, the stability benefits of required reserves were also estimated to be substantial and the minimum reserve requirements were increased in Dodd-Frank Wall Street Reform and Consumer Protection Act (commonly referred as Dodd-Frank). Aside from setting more severe high-quality capital requirements, so called Volcker Rule (§ 619 of Dodd Frank) restricted banks from participating in certain risky hedge fund activities. Therefore, the stability benefits of reserve requirements and other regulations were recognized after decades of financial deregulation (i.e. important regulation law Glass-Steagall was repealed in 1999).

So, we have discussed the efficiency and stability implications of reserve requirements and interest on excess reserves. IOER is basically a stable policy tool for central bank to change its interest rates, while reserve requirements remain as an important tool for controlling banking sector stability and risk-taking. Most developed countries and their respected central banks followed the example set by Fed after the financial crisis and begun purchasing assets in Quantitative Easing programs increasing their monetary base with excess reserves in their respective systems. I will now shortly discuss the differences in using IOER as monetary policy tool in Japan and EU compared to US.

The most important difference is that in Japan and EU, central banks have kept IOER at negative territory unlike in US, where Fed has only paid positive interest rates on excess reserves. Many explanations have been presented on this peculiar aspect, but the major reason for ECB and BoJ to keep their interest on reserves below zero was to encourage banks to increase their lending by penalising reserves. The competitiveness of US banks has been historically better than in Europe and Japan, so this could be one rationale behind this policy difference. The growth in bank lending and credit growth has also been lacklustre in Europe after 2008 due to political risks stemming from Greek debt crisis and divergence between southern and northern states in EU (Figure 11).

Figure 11: Annual growth rate of bank lending in US, Euro Area and Japan



Therefore, while in US the IOER plays a major part in monetary policy and interest rate setting, ECB and BoJ mainly use it as an instrument to boost lending. It remains to be seen, whether other central banks follow the example of Fed and begins using IOER later as a tool for quantitative tightening when they begin normalising their interest rate policies.

1.4 Exit strategies for monetary policy

The big question regarding monetary policy today is, whether central bank can ever normalize its interest rates and the size of its balance sheet without negative unforeseen consequences in the real economy and especially in the banking sector. Quantitative tightening refers to the policy shift towards normal monetary policy: smaller Federal Reserve balance sheet with less excess reserves and higher interest rates. It is though unclear, what the Federal Reserve balance sheet size will be after the normalization. In this section, I will briefly discuss different policy options for Fed to tighten its monetary policy.

Federal Reserve has three options for normalizing its monetary policy: first, it can leave its current escalated levels of excess reserves unchanged by paying high enough interest rate on reserves for their demand to be kept at current levels. This would mean, that balance sheet size will remain elevated until further notice. Second option is to substitute the reserves in the market with other different instruments in Federal Reserves' disposal: bills, reverse repos or term deposits. Third option is to start selling assets purchased during QE-programmes back to the markets. As the assets in balance sheet shrink, also the amount of reserves in the liabilities will shrink to the same extent. The third option is the only viable solution, if Federal Reserve aims to reduce its balance sheet closer to pre-crisis levels. Other two options leave balance sheet elevated but reduces the amount of excess reserves in the banking system. (Berentsen et al. 2018)

So far, Federal Reserve has indeed committed to reducing its balance sheet closer to pre-crisis levels from current $ 4.5 trillion. The plan is to gradually increase the monthly balance sheet shrinking to maximum of $50 billion (FOMC, 2017a. Addendum to the policy normalization principles and plans). The plan is however to hold more reserves after the normalization than before the crisis. Estimations for the balance sheet size range between $ 2-2.5 trillion and the likely amount of excess reserves might be as low as $500 billion (Jim Bullard [St. Louis Fed], 2018). Be that as it may, the conclusive answer for likely balance sheet size has not yet been communicated by the FOMC.

It seems that, Federal Reserve has opted to combine the reduction of reserves by absorbing them with reverse repos while it has also begun its gradual balance sheet reduction operation by either letting its asset holdings run into maturity or selling them back to markets. So far, Federal Reserve balance sheet has however only reduced by nearly $400 billion (Note, that the QT has only begun with gradual increases during 2018).

2. Demand for Reserves

In this chapter, the demand for reserves is discussed in greater detail. What implications does the current safe asset scarcity have on the demand for reserves and how Federal Reserve can manipulate the shape of the demand curve to its liking? First, I will discuss previous research on the subject and the behavior of banks in the market for reserves. Then I will examine the interest rate policy of Fed and how the central bank can change banks' behavior by incentivizing reserves via interest on reserves.

2.1 Longing for safe assets and hedging against uncertainty

Thus far, I have covered the rationale behind Federal Reserve's new monetary policy regime with abundant reserves and interest on excess reserves as a tool for interest rate targeting. In this chapter, I will discuss different reasons for depository institutions to hold larger amount of excess reserves in their balance sheets. Central bank has supplied the markets with trillions of dollars' worth of reserves, but where does the demand for these assets come from? My argument in this chapter is, that tightened minimum reserve requirements and other bank regulations such as Dodd-Frank have forced banks to adopt more reserve-oriented balance sheet policies. This together with increased banking sector risks in post-financial crisis era and decreased safe asset supply have provided favourable environment for current monetary policy to flourish. Next, I will discuss these considerations in more detail.

The relationship between excess reserves and Federal funds rate has been an important research topic in monetary economics for long time. For example, James Dow (2001) found a negative relationship between Fed funds and excess reserves. One percentage increase in rates was associated with roughly $ 120 million decrease in excess reserve holdings. The data was collected from the 1990s and has some important message to consider in our current context. First of all, no interest was paid for excess reserves until 2008, so banks willingness to hold excess reserves was due to changes in short-term interest rates and regulatory changes. Since short-term interest rates are in essence opportunity costs for holding excess reserves, the changes in rates should have inverse relationship with reserve holdings.

Dow was not the first one to find this inverse relationship as feasible assumption in monetary policy: for example, Hamilton (1997) found even larger elasticity than Dow did. One percentage-point change in Federal funds rate was associated with as much as $300 million change in excess reserve holdings. Note, that both results were "only" in millions of dollars, as nowadays the amount of excess reserves are calculated in billions and even in trillions. The simple comparison between different

rates and amount of reserves, which was used in these research papers, was rather simple and could not really take into account different changes in regulatory environment of that time. The rate spread approach to amount of reserves has been researched only recently (most notably, Reis 2016), which provides more sophisticated results on the subject (since the rate spreads themselves provide important information on the opportunity costs between different rates and services).

Another proposition from Dow is that excess reserves provide a buffer for banks against uncertainty about their own balance sheet. This implies that demand for excess reserves should then increase with uncertainty. The general model of the precautionary demand for reserve holdings by Poole (1968) assumed that increase in transactions deposits increases uncertainty: simply put, more banking activity causes more balance sheet uncertainty that again increases demand for relatively safe excess reserves. This assumption holds, when there is a scarce supply of safe assets in the markets and excess reserves are easily acquired. Central bank can then manipulate the shape of demand curve by increasing minimum reserve requirements or restricting risk taking, which in essence forces banks to hold more safe assets as a hedge against its risky investments. Now, let us consider the post-GFC (Global Financial Crisis) monetary policy for a moment. Central bank has indeed forced banks to hold more safe assets by increasing regulations (i.e. Dodd-Frank). Simultaneously it has decreased the supply of safe assets in the markets by purchasing relatively safe government treasury bonds and adding them in its balance sheet. Federal Reserve and other central banks have then substituted safe assets in exchange for excess reserves.

2.2 Demand curve alteration: how it's done

Banks face a choice between highly liquid reserves and less liquid short-term debt obligations such as 3-month T-bills that can be used to finance their purchases in

interbank market. Prior paying interest on reserves, this meant a trade-off between liquidity and the possible rate of return banks got from holding securities.

When a bank needed a quick credit to finance its daily trades, it needed to sell securities to meet its credit in reserve markets (Fedwire). Reserves were scarce, so one had to borrow them from other banks. If for instance bank had excess reserves (to meet its requirements and to use them as a currency in trades), it would not need to rebalance its balance sheet but only would pay directly with reserves.

Now, as markets for reserves are saturated, the need for borrowing in interbank markets has declined. This can also be seen as Fed objective to reduce the perceived risk in the interbank market that was deemed high after the financial crisis and banks were more cautious in dealing with other banks in reserve trades. (Hendrickson, 2017)

Now with abundant excess reserves and strongly positive interest paid on excess reserves, reserves are no longer just a law-enforced liquidity requirement, but also a highly liquid, interest-bearing monetary asset for depository institution. To put it the other way, banks no longer need to make a trade-off between liquidity and rate of return like they used to make. For bank productivity this has of course some important implications: settlements of payments in the interbank market becomes more efficient as there is no longer market friction caused by the time and effort it takes to sell the less-liquid assets to maintain banks daily solvency.

Another important implication is that paying interest on excess reserves makes monetary policy less effective in a sense of portfolio reallocation mechanism: why would a bank that is credited with freshly printed interest-bearing reserves allocate its reserve-holdings if it is awarded with high interest for only holding the reserves. IOER was higher than 3-month T-bill for long time after the financial crisis, so the substitution was mainly between reserves and T-bills and no other reallocation then would emerge. (Bernanke,2010)

Federal Reserve has in a way destroyed the original market mechanism in the federal funds market and replaced it with their own liking. With IOER, Federal Reserve had a negative and significant effect on the demand for daylight overdrafts and indeed increased the demand for bank reserves (Hendrickson, 2017). Also, by buying highly valued T-bills (safe assets), Federal Reserve forced banks to adopt more reserve-rich strategy. In hindsight then, QE was mainly a tool for changing banks' behaviour in the short-term interest market (to become more reliant on reserves rather than overnight facilities) and made a significant impact on interest maturity of outstanding US public debt.

2.3 Policy implementation

When reserves are scarce, banks borrow reserves from other depository institutions to meet their demand for reserves. Those with excess reserves want to get rid of their excess holdings while banks in shortage of reserves need to acquire them in the interbank market. When reserves are plentiful, like today, the need for interbank lending decreases. As a result, share of interbank trades in the federal funds market has decreased to unforeseen low levels. (Armenter & Lester, 2017)

Federal Reserve Open Market Committee laid down the ground rules for normalizing its monetary policy already in September 2014: Committee intended to use IOER as its main tool for raising the federal funds rate target while using Overnight Repurchase agreements (ON RRP) facility only when necessary. ON RRP rate is the other important policy tool for Federal Reserve, which provides short-term capital and collateral lending for depository institutions at fixed rate. Its policy significance has in recent years fallen (demand for reverse repos shrunk to all-time lows in 2018) and instead IOER has become the most important tool in Fed's disposal for interest rate targeting.

To give an example for the implications one can take away from this: Overnight reserve repurchase agreements are transactions, where Fed sells a security to a bank

and agrees to buy it back the very next day. This temporarily changes the composition of Federal Reserve liabilities and it is paid positive rate offered by the Federal Reserve. The rate of ON RRP is set at the lower end of the Federal Reserve interest rate target. In general, any bank that is eligible to use ON RRP facility, is then unwilling to invest its funds overnight at lower rate than the rate set by the Fed with other counterparties. If Fed moves IOER (that is set at the higher end of Fed interest rate target level) and ON RRP (that is set at the lower end of Fed interest rate target level) in parallel keeping the spread between the two rates constant, also the target zone (usually 0.25 spread) moves one-to-one with the change in the two rates. In theory, the effectiveness of this kind of rate adjusting strategy was positive already before Federal Reserve begun implementing this strategy starting from 2016 (Armenter & Lester, 2017).

Where the market rate between the two policy rates actually lies is determined by the volume of activity: if most interbank short-term funding is being handled with reserves, market rate hikes closer to the high end of the target spectrum. If on the other hand reserves become scarce, banks are forced to use overnight facilities.

Figure 12: Target Range

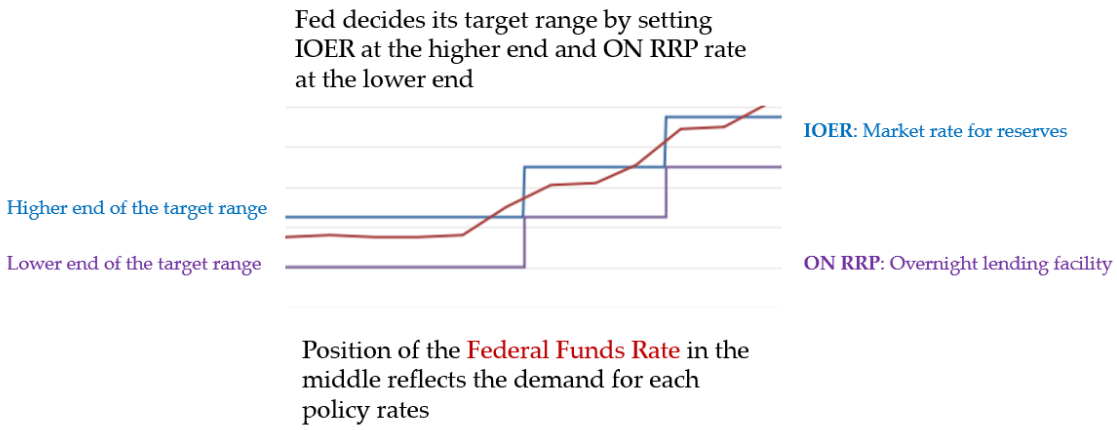


Figure 13: Spread between Federal Funds rate and IOER has shrunk during the tightening phase (Board of Governors of the Federal Reserve System,2018)

So, for a qualified depository institution, there are two alternatives in the federal funds market: Use Overnight Facility to borrow reserves from other banks or to use own excess reserves. Lately, federal funds rate has been hiking towards the upper end of the target range (see Figure 13 above), which implies that depository institutions are using more and more of their excess reserves to meet their daily monetary needs. This could be due to shortage of dollars which makes cash more expensive in interbank markets. Then the only viable option is to shrink excess reserves and substitute them to more liquid form of money.

Federal Reserve has also started to change the spread between ON RRP and IOER when it increased the IOER by only 0.2 % while raising the ON RRP rate by 0.25 %. This could imply some policy shift considering IOER in the future, which Fed is already starting to examine. On the other hand, Fed might want to control the speed at which the excess reserves are currently shrinking by trying to steer some banks back into the ON RRP markets.

Figure 14 & 15: How Federal Funds rate has moved in the target range during 2012-2018 (St. Louis Fed)

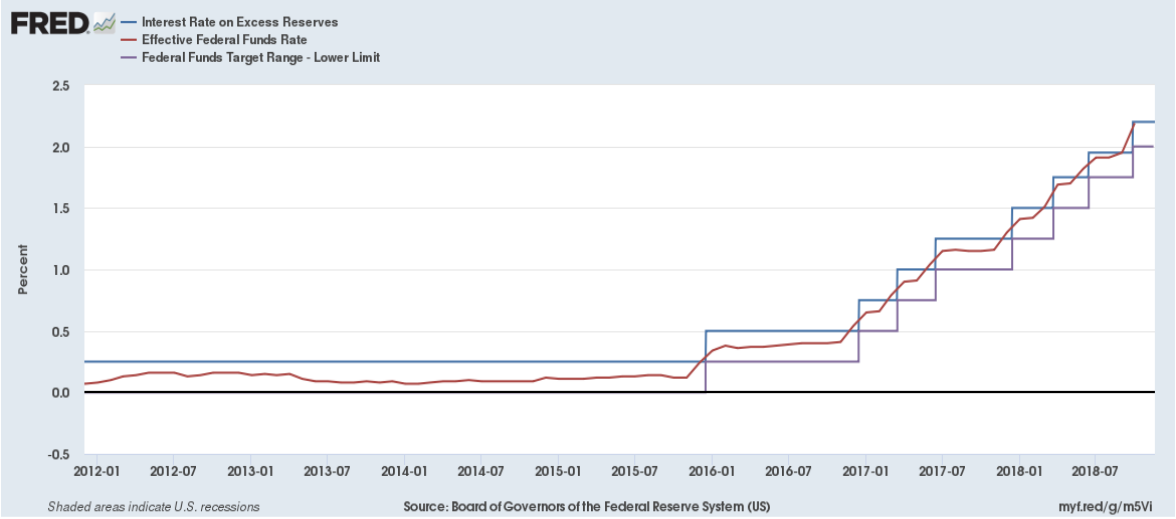
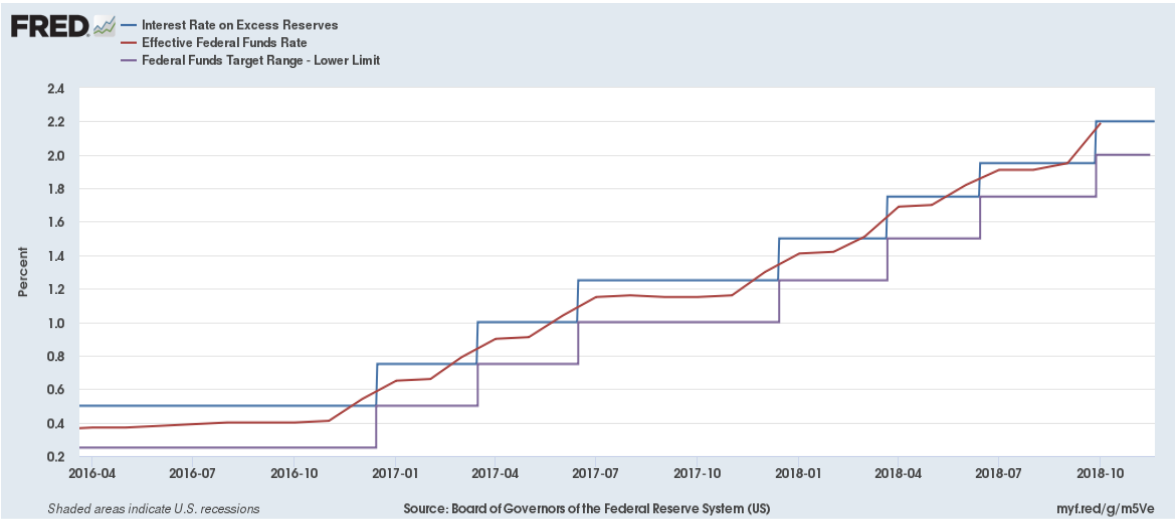


Figure 15: Federal funds rate has creeped higher towards the IOER (spread decrease) 2016-2018



3. Empirical Approach

The empirical part of this thesis is a replication of study made by Ricardo Reis (2016) on the demand for excess reserves. Reis argued that the markets were effectively saturated with reserves since late 2011 (after the end of second round of QE), which made it possible for the central bank to increase or decrease its reserve supply independently from its interest rate policy. Reis argued that since markets were properly saturated, the third round of QE beginning in 2012 had no real effect on interest rates and was only used to increase further the supply of excess reserves in the US banking system. Indeed, his regression showed, that the supply of excess reserves had long surpassed the horizontal part of the demand curve (please revisit Figure 10 if needed). I will continue to work on this same topic here.

My hypothesis in this study is that markets have lost their saturation with excess reserves at some point during 2018, which effectively means, that Federal Reserve can shrink its reserves by adjusting the spread between IOER and its interest rate target. Fed has already tested this in the market twice during 2018, when it surprisingly raised IOER only by 20 points while raising its target by 25 points higher in June and later in September (see shrinking spread in figure 13). By playing with the spread between federal funds rate and IOER, Fed can force financial institutions to move away from excess reserves and begun meeting their short-term monetary needs with treasury bills or notes. Therefore, I expect to find inverse relationship between the spread of IOER-FF (Interest on Excess Reserves – Federal Funds rate) and the change in held excess reserves by depository institutions. Simply put, when Federal Funds rate falls closer to the lower end of the interest rate target zone, it becomes more tempting for depository institutions to hold excess reserves as opportunity cost for federal funds rates increases: banks get better comparable rate of return from reserves.

In addition, when the spread between IOER and short-term Treasury bills (3-month T-bill) increases, banks are more inclined to hold more excess reserves to meet their

short-term debt obligations in the federal funds market. Higher T-bills mean that it is more expensive for banks to liquidate these holdings compared to dealing their daily operations with reserves. Therefore, we should see positive relationship between IOER – T-bill spread and the amount of excess reserves.

The end product of this empirical work is a simple time series regression of two different rate spreads to the amount of excess reserves held by the depository institutions. Reis used log real reserves as the dependent variable in all regressions, while using either the spread between IOER and FF or IOER and 3-month T-bill as the explanatory variables. Table 1 explains his approach: explanatory variables are regressed one at the time with and without estimated trend (columns 1-4) while column 5 gives results for both variables during time period of 2011-2016. This was the time frame markets for reserves were expected to be saturated. Column 6 provides an important comparison point, since the observation period includes time before 2011. Since the parameter estimates (measuring the semi-elasticity of demand for reserves in respect to the interest rate spreads) of results is higher during the time when markets were not saturated for the whole period, we can assume, that the demand curve has indeed moved further to the right after 2011 (semi-elasticity of reserves closer to zero). Unsurprisingly since the markets are not saturated during most of the observation period in column 6, results are more significant and shows larger elasticity of demand for price changes (measured as spreads IOER-FF or IOER-T-bill). These results reflect the change from elastic part of the demand curve to horizontal where amount of reserves no longer have effect on short-term rates.

Reis' main findings in his regression were that a one standard deviation increase in the difference between the interest on reserves and federal funds rates (of 4 basis points) would lower the demand for reserves by 0.8% (see column 5 in Table 1). The semi-elasticity of reserves to interest rates were not statistically different from zero,

which can be seen as indicating proof that markets were nearly wholly saturated during the time period after late 2011 to 2016.

Table 1: The Demand curve for reserves (Reis,2016)

Variables	(1) Reserves	(2) Reserves	(3) Reserves	(4) Reserves	(5) Reserves	(6) Reserves
$i_{\text{Reserves}} - i_{\text{FederalFunds}}$	-0.174		-0.119		-0.199	-0.467**
	(0.112)		(0.112)		(0.127)	(0.185)
$i_{\text{Reserves}} - i_{\text{Tbill}}$		0.0140		0.187	0.0878	0.352
		(0.156)		(0.162)	(0.171)	(0.219)
Obs	53	53	53	53	53	88
Trend	No	No	Yes	Yes	No	No
F Test	2.40	0.01	1.93	2.40	1.40	3.49**
Adj. R sq.	0.022	0.019	0.033	0.043	0.010	0.087

Notes: The left-hand side in all regressions is the difference in log real reserves. In columns 1 to 5, the sample goes from December 2011 to June 2016; in column 6 it starts in December 2008. A time trend is included in columns 3 to 6. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

All the data for my replication is constructed from Federal Reserve Data. I expand Reis' data from late 2016 to November 2018. The measure for reserves is the natural logarithm of monthly real reserves (adjusted for CPI inflation). I also use two measures to capture the price of reserves in the markets: the IOER-FF spread and the spread between IOER and 3-month Treasury bill market rate. As argued by Reis, these measures should correctly capture the opportunity cost of holding excess reserves to short-term funding needs of depository institutions. I will use simple regression evaluate how the relationship between rate spreads and the amount of excess reserves has worked out during the observation period.

My approach is, here due to its simplicity, far from perfect and most likely will contain some omitted effects that are not correctly observable in my data. However, observing the spreads between prices and the real amount of excess reserves should correctly give clues of the price mechanisms in the short-term money market. In the future though, bank-level data on reserves would be more satisfactory approach, since it would better capture the differences between institutions in federal funds

market. It is reasonable to believe, that there are differences between different depository institutions in their saturation for reserves and as reserves shrink, it is the smallest institutions that are most vulnerable to interest rate increases (as their reserves intuitively fall towards the required reserves first and hence face liquidity constraints first of all depository institutions).

3.1 Regression results

Table 2: Regression results with my data

VARIABLES	(1) D.lnrres	(2) D.lnrres	(3) D.lnrres	(4) D.lnrres	(5) D.lnrres	(6) D.lnrres	(7) D.lnrres
iRiF	-0.0240		-0.0856		-0.177*	-0.323***	-0.192
	(0.0922)		(0.0825)		(0.105)	(0.117)	(0.179)
iRiTB		0.0798*		0.0353	0.134**	0.214**	0.101
		(0.0408)		(0.0518)	(0.0576)	(0.0818)	(0.0837)
tunit			-0.000490***	-0.000382*			
			(0.000162)	(0.000194)			
Observations	83	83	83	83	83	118	31
Trend	No	No	Yes	Yes	No	No	No
F Test	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adj. R sq.	-0.0113	0.0293	0.0716	0.0661	0.0531	0.0762	-0.00288

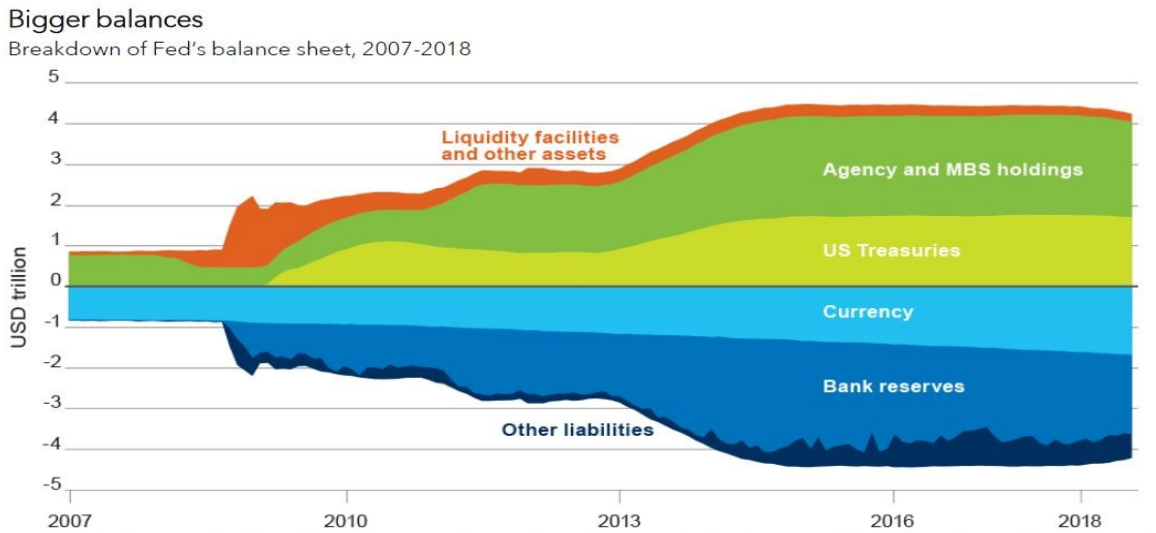
Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Results for my regression are shown in table 2 above. First five columns are similar to Reis' regression but added with data from summer 2016 to November 2018 (number of observations now 83). Observations begin in May 2016, when markets for reserves were effectively saturated after the second round of Quantitative Easing. My results indicate little lower explanatory value for the spread between IOER and Federal Funds rate (iRiF), but the results seem to be slightly more accurate with lower standard errors than Reis. As expected, IOER-FF is negatively related with Amount of held reserves. Demand for reserves seems to have been very close to horizontal: results are very close to zero and have better explanatory value statistically than the previous regression with more limited timeframe.

Column 6, which contains all months from 2008 to late 2018, again reflects the highest effect in IOER-FF spread. Since the data includes not only the time when reserves

were more scarce and begun to rise significantly, but also time period beginning from 2016 when simultaneously Federal Reserve begun its interest rate hiking and reserves started to decrease. Value of reserves has dropped nearly one trillion dollars since then. Markets then might not be completely saturated with reserves anymore and the increasing spread between these rates by four basis points decreases the amount of held reserves by 1.2 % (Reis: 0.8 %). My results then indicate a greater economic significance of rate spreads than earlier research and imply that, when markets become less saturated, the interest rate spreads will likely lead to steeper reduction in held reserves than expected. This provides important implications for monetary policy as well, since it is in Federal Reserve's interests trying to withhold the inflationary pressures from decreasing excess reserves. If Federal Reserve cannot control the change in its liabilities (excess reserves flight to safety faster than Fed is able to reduce its assets), then we should assume to see increase in working monetary base (monetary base excluding excess reserves), which would again increase inflationary pressures in money markets. In Figure 16 this is already visible as the share of "other liabilities" has increased after 2016: Fed has substituted some excess reserves for bills, reverse repos or term deposits as it can't shrink its balance sheet too fast in this situation.

Figure 16: Federal Reserve Balance Sheet composition



Sources: BlackRock Investment Institute and Federal Reserve, with data from Thomson Reuters, August 2018. Notes: The chart shows the breakdown of the Fed's total assets and liabilities.

In the column 7 then, data from June 2016 until November 2018 is shown. My aim was to observe the price effects of only the period, when Federal Reserve begun raising its interest rates, but due to low number of observations during this period (31) it is very difficult to make any bigger assumptions of this and the significance of these results remain small. To better identify, whether there have indeed been any significant structural changes in my data after 2016, I run a simple Chow test (Chow, 1960). This test should tell whether the regression coefficient is different when data set is split. I split my observations to two parts: first part is from 2008 to December 2015 and part two is from January 2016 to November 2018.

Null hypothesis of this test is that there is no structural change between periods (there is no break point in the data). If we are able to reject this hypothesis, there has been a significant change in demand for reserves after 2016. The regression tables for both time periods and formula for Chow test can be found in the Appendix. Here, result for the test statistic 41.45 is higher than the critical F-value 5.89, meaning that the null hypothesis can be rejected and hypothesis of structural change in the data will stand[1]. One can then argue, based on these results, that interest rate spreads are of large economic importance for the future of monetary policy and will affect the amount of reserves in the system heavily as the reserves shrink more from their current status. We could assume to see more relevant changes in the saturation of reserves during next year, if the current quantitative tightening continues as expected.

Longer observation period in the future though would of course provide better answers on whether markets are no longer saturated. If we would observe greater effect in IOER-FF, it would be safe to argue that the demand for reserves is closing in to the elastic part of the demand curve. Then markets would no longer be saturated

[1] Test gives very similar results with observations split only after June 2016.

and Federal Reserve could push down its reserve holdings (and consequently its balance sheet size) by tweaking the spread between its policy rates.

The sign of the IOER - T-bill spread is as expected. Results indicate that as the spread between IOER and 3-month T-bill increases, also the amount of excess reserves will increase significantly. One possible reason for this might be, that as the US government debt keeps increasing at alarming speed, it will also push excess amount of AA-grade collateral (in the form of T-bills) to the market. As T-bills become abundant, the need for using ON RRP for banks decreases as they can also meet their needs in the federal funds market with using their excess reserves (that increase as US treasury prints more debt). However, this might also be a warning sign that liquidity in the federal funds markets is drying up fast: overnight facility is already non-existing and excess reserves are now shrinking fast: nearly 400 billion worth of reserves has already vanished this year.

4. Discussion

My study strengthens the view that the situation in money markets had already changed after the Fed ceased QE and began QT. Even if, the results are not completely straight-forward and explanatory, it is visible, that some profound changes are already happening in demand for excess reserves in the market during the QT-phase of monetary policy. Still, my empirical work provided some important implications on how amount of excess reserves depends on changes in short-term interest rates. For future research, more detailed bank-level data would be needed to examine the behaviour of depository institutions during Quantitative Tightening. Moreover, as IOER and Federal Funds rate have reached parity just at the time of writing this paper, it will be interesting to see what effects the inversion of yield curves in short-term interest markets has.

Risks are in principle, known unknowns: they are measurable shock events that could occur with some probability in the future and can be hedged against. Unknown unknowns on the other hand, are immeasurable uncertainties. Something that is either impossible to consider as a possibility or its probability is deemed too insignificant for it to be considered as a threat. At this point, shrinking of Federal Reserve balance sheet could pose some unforeseen threats to the global financial system: main concern is that liquidity in the short-term interest market dries up suddenly, if Fed keeps on hiking its rates too fast. On the other hand, increasing US public deficit (which is financed with freshly issued T-bills) might provide an important safe asset supply to the markets when it needs it the most. This of course is dependable on the fact, that markets keep trusting in US governments' ability to meet its outstanding debt obligations. Possibility of complete loss of trust however remains somewhat unlikely, since the bond prices are currently at all-time highs.

Thus far, Federal Reserve does not see any connection between reduction in excess reserves and upward pressure in federal funds rate (FOMC, September 2018). The blame for rising short-term rates (especially Treasuries) are due to glut of T-bills in the market, as the current US administration runs all-time-high budget deficits that it finances with fresh Treasury issuances. The increase in supply of Treasury bills has also led to a quick increase in yields even of the short-term T-bills, that as we have discussed, are important substitutes for banks in short-term liquidity management. Increased yield differential between IOER and 3-month T-bill then has raised the incentive for holding these bills, while the risks of rising public debt does not seem to be any concern for financial markets at the moment.

It is though difficult to outright approve the rising T-bill glut as the only viable explanation for sharp decrease in reserve holdings while FF rate is seemingly getting out of Feds' direct control. It can be claimed, that when Federal Reserve decreased the spread between IOER and ON RRP to 20 basis points, it also affected

the incentives for holding excess reserves to the extent, that some depository institutions decided to bail out their reserve holdings for assets with better expected rate of return: Treasuries. As Fed has already communicated its rather hawkish interest rate policy for the upcoming year and has implicated already that it will not increase IOER at same pace than its target range for FF, it becomes more lucrative for banks to reallocate their asset holdings away from reserves. Research suggests, that central bank might need to adopt some additional tools to manage its quantitative tightening without causing inflationary pressure from speculative run out of excess reserves. Possible tools to offset speculation within central banks' liabilities could be increased reserve requirements (involuntary excess reserves) or politically hard fiscal-policy intervention (Bassetto & Phelan, 2015).

A sharp decrease in reserves does not directly imply that demand for reserves is currently not saturated, but the future expectations for interest rates could already alter the demand curve in a way, that is not modelled in current theories of demand for reserves. Therefore, future expectations for federal funds rate should be introduced to theory of demand for excess reserves in future research.

Even though Federal Reserve does not communicate any sign of concern of its interest rate targets and heavy issuance of Treasuries are not necessarily under their mandate to worry about, it is clear that the Fed is monitoring the rate environment with growing concern. As the federal funds rate has already surpassed the IOER and is closing the upper limit of its target range, it is reasonable to believe Fed is already afraid of losing control over its interest rate targets. FOMC conducted a survey during October-November on whether banks will withdraw their reserve holdings if FF would be higher than IOER (FOMC Minutes, November 2018). Reportedly, banks were inclined to increase their lending in overnight repo markets (ON RRP) if FF would be modestly higher than IOER for longer period of time.

In addition, the banks' lowest comfortable amount of excess reserves after QT is surveyed to be as high as $600 billion (Senior Financial Officer Survey, September

2018). That is, banks are not willing to let go of the current reserve-surplus environment. At current tightening pace, the level of reserves would most likely be closing this level already in 2020. Moreover, the same survey indicated that banks would most likely reduce their reserve holdings substantially if the opportunity cost between short-term interest rates and IOER (spreads) would increase by more than 5 basis points. Therefore, my earlier hypothesis that Fed can force depository institutions to let go of their excess reserves holdings by adjusting the spread between federal funds rate (and short-term T-bill rates) and IOER is seemingly correct.

This result adds to Federal Reserve's concerns over the stability of their floor system monetary policy and gradual balance sheet reduction. Moreover, Federal Open Market Committee has already directed the Desk (New York Fed trading desk) to undertake open market operations when necessary to maintain FF at its target range. Fed is then already coming back to its old tools of interest rate targeting implying, that the faith in floor system is teetering as reserves shrink and the interest rates are going up. It is then reasonable to forecast, that the Fed is forced to move back to its previous Corridor System monetary policy earlier than expected if the demand for reserves becomes more elastic.

This rather odd situation in the federal funds market implies that something extraordinary is about to happen upcoming months. There already exist signs that demand for reserves is no longer saturated. Even though the signs remain weak, it seems that markets are already pricing in the expectations of reserve scarcity in the federal funds market. For Fed, a short pause in the hiking cycle or at least reassuring communication of its future policy shifts, would be a good idea to calm the current market situation and gain back control over increasing federal funds rate. Ending the QT prematurely, however, could stir unwanted speculation and uncertainty in the markets about the direction of the monetary policy. Federal reserve chairman Jerome Powell tried to mitigate these fears in January 2019[2]: Fed would continue to

[2] "Statement Regarding Monetary Policy Implementation and Balance Sheet Normalization", January 2019

implement monetary policy in the floor system with an abundant supply of reserves. However, Powell did issue a warning that the current estimate for the supply of reserves to keep markets saturated is quite uncertain and might even be larger than they expected in the early 2018. This implies, that Federal reserve is indeed even more likely to end its balance sheet reduction earlier than it had originally intended. This again strengthens the view, that the demand for reserves is currently moving in to the elastic part of the demand curve as my results suggested. For Federal Reserve, the difficult part of QT will then be to evaluate the right supply of reserves and hence the right size of the balance sheet before their current floor system becomes ineffective.

Even the president of the United States, Donald Trump, has famously criticised Federal Reserve in public about raising rates and shrinking the balance sheet too fast:

"I hope the people over at the Fed will read today's Wall Street Journal Editorial before they make yet another mistake. Also, don't let the market become any more illiquid than it already is. Stop with the 50 B's. Feel the market, don't just go by meaningless numbers. Good luck!"

- Donald J. Trump, 18 December 2018

Direct political criticism towards independent Federal Reserve is quite unprecedented in modern times, even though there are some lessons from history about the presidential interference in the Feds' policies. Famous examples include Lyndon B. Johnson physically attacking then-Fed Chairman William McChesney in 1965. Richard Nixon again forced Chairman Richard Burns to ease monetary policy before 1972 election that has been seen as dangerous precedent to upcoming inflation-cycle that was not eased until the 1980s. Even Ronald Reagan administration pressured chairman Paul Volcker not to raise rates further before election of 1984[3]. Aside from that incident, the success of Paul Volcker Fed chairmanship could not have

[3] Paul Volcker in his 2018 memoir "Keeping At It: The Quest for Sound Money and Good Government" by Christine Harper and Paul Volcker

happened without wide mutual respect and trust between the administration and the Federal Reserve.

The newly escalated populist anger against Fed's actions however could pose unprecedented dangers to the credibility of US monetary policy and global QE as well. Any sign of backing off from the monetary policy tightening after stark criticism could be interpreted as Federal Reserve giving in to political pressure. Historical predecessors indeed show, that weak Fed Chairs have the tendency to yield against the presidents will. Real danger of course is, that Fed will not be able to raise interest rates enough before the next crisis, which would leave little room for monetary policy to operate. The previous toolkit of lowering interest rates to zero and issuing more reserves via QE would be insufficient as the balance sheet remains elevated and rates are still historically low.

The uncertainty about the short-term monetary policy is indeed climbing. Federal Reserve quite surprisingly communicated about the possible drawdown of balance sheet reduction in January 2019 FOMC meeting. As said, this could prove to be a good idea to calm the markets but slowing the pace of QT could on the other hand send all the wrong signals about the competence and independence of the central bank. Also, it would of course not solve the problem of increasing supply of T-bills in the market and growth in their respective yields, which are also a growing concern for Fed, that has also its own skin in the game as one of the biggest shareholders of Treasury bills. Even though it is not directly under Federal Reserve mandate, this effectively means that asset price stability is under Feds' interests, since Treasuries and mortgage backed securities make up a large portion of Federal Reserve balance sheet.

Moreover, if bonds market prices are declining due to increase in their yields (bond price usually decreases as its rate of return increases), Fed is more likely to face more paper losses by rolling over its balance sheet via QT. As Federal Reserve calculates its balance sheet with face value of its assets, the difference in face value and market

value will cause Federal Reserves' net worth to fall negative as the central bank cannot offset its liabilities (that are calculated in face value) by same amount as assets (that are calculated now in market value). Theoretically, this does not matter and won't put Fed's solvency into jeopardy, but it might put the credibility of Federal Reserve's competence into question. This again implies, that Fed might need to end its balance sheet reduction earlier than expected, to keep its balances and credibility in check.

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Appendix

Chow test Formula:

$$F = \frac{(RSS_1 - RSS_3)/(k+1)}{RSS_3/(N-2k-2)}$$

Simple regression table for whole period and for for 2008-2015 & 2016-2018

```
. reg D.lnrres iRiTB iRiF
```

Source	SS	df	MS	Number of obs	=	118
				F(2, 115)	=	5.83
Model	.026639085	2	.013319543	Prob > F	=	0.0039
Residual	.262933927	115	.002286382	R-squared	=	0.0920
				Adj R-squared	=	0.0762
Total	.289573012	117	.002474983	Root MSE	=	.04782

D.lnrres	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
iRiTB	.213609	.0645793	3.31	0.001	.0856898	.3415282
iRiF	-.322861	.1172475	-2.75	0.007	-.5551058	-.0906162
_cons	.0101999	.0117038	0.87	0.385	-.012983	.0333828

```
. reg D.lnrres iRiTB iRiF if tunit<85
```

Source	SS	df	MS	Number of obs	=	83
				F(2, 80)	=	5.89
Model	.028310521	2	.014155261	Prob > F	=	0.0041
Residual	.192114611	80	.002401433	R-squared	=	0.1284
				Adj R-squared	=	0.1066
Total	.220425133	82	.002688111	Root MSE	=	.049

D.lnrres	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
iRiTB	.412234	.1281029	3.22	0.002	.1573011	.6671669
iRiF	-.5469051	.1776662	-3.08	0.003	-.9004721	-.1933382
_cons	.0076517	.0180607	0.42	0.673	-.0282903	.0435937

```
. reg D.lnrres iRiTB iRiF if tunit>84
```

Source	SS	df	MS	Number of obs	=	35
				F(2, 32)	=	0.96
Model	.003292893	2	.001646446	Prob > F	=	0.3953
Residual	.055139514	32	.00172311	R-squared	=	0.0564
				Adj R-squared	=	-0.0026
Total	.058432407	34	.0017186	Root MSE	=	.04151

D.lnrres	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
iRiTB	.0942019	.0692926	1.36	0.183	-.0469426	.2353464
iRiF	-.1518852	.1454302	-1.04	0.304	-.4481168	.1443464
_cons	-.0039755	.0146882	-0.27	0.788	-.0338943	.0259434